Dialysis and its Application

Hongbao Ma *, **, Yan Yang **, Shen Cherng ***

* Bioengineering Department, Zhengzhou University, Zhengzhou, Henan 450001, China, mahongbao@zzu.edu.cn; hongbao@gmail.com, 01186-137-8342-5354

** Brookdale University Hospital and Medical Center, Brooklyn, NY 11212, USA, youngjenny2008@yahoo.com, 347-321-7172

** Department of Electrical Engineering, Chengshiu University, Niaosong, Taiwan 833, China, cherngs@csu.edu.tw; 011886-7731-0606 ext 3423

Abstract: Dialysis is a renal replacement therapy that provides an artificial replacement for kidney disfunction, and it is a life support treatment but not treat kidney diseases. Dialysis is based on the principle of the diffusion of solutes along a concentration gradient across a semipermeable membrane. There are three main types of dialysis: hemodialysis, peritoneal dialysis and hemofiltration. [New York Science Journal. 2009;2(1):91-96]. (ISSN: 1554-0200).

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1. Introduction

Kidney is an important organ in animal to remove waste from the body, such as potassium and urea, as well as free water from the blood. Under the healthy condition, kidneys remove waste products from the blood and also remove excess fluid in the form of urine (Minuth et al. 2008). Disfunction kidney could loss these functions, which is a serious disease that damages many people’s normal life and even be fatal. There are millions of people who are suffered from kideny disfunction. Dialysis is a renal replacement therapy that provides an artificial replacement for kidney dysfunction, and it is a life support treatment but not treat kidney diseases, which is based on the principle of the diffusion of solutes along a concentration gradient across a semipermeable membrane. In dialysis, blood passes on one side of a semipermeable membrane, and a dialysis fluid is passed on the other side. By altering the composition of the dialysis fluid, the concentrations of undesired solutes (potassium and urea, etc) in the fluid are low and desired solutes (such as sodium) are at their natural concentration as in healthy blood. The undesired solutes, i.e. waste, then diffuse across the membrane into the dialysis fluid and are removed, and the desired solutes will be kept in the natural concentration. Dialysis may be used for very sick patients who have suddenly lost their kidney function or for quite stable patients who have permanently lost their kidney function. Dialysis treatments could play the functions to remove waste from the body, instead of the kidney’s function. Dialysis lets the blood into the comparative normal condition for the renal dysfunctional patients (Verbeke et al. 2007). Bacterial kidney disease is a systemic disease that threatens the expansion of both cultured and wild salmonids worldwide (Eissa, 2006). The progressive increase in the mean age of dialysis patients associated with increasing comorbidity factors such as the presence of cardiovascular disease and diabetes have significantly worsened patients' clinical status and tolerance to hemodialysis (Santoro et al. 2007).

2. Theory of Dialysis

Dialysis is based on the principle of the diffusion of solutes along a concentration gradient across a semipermeable membrane. In dialysis, blood passes on one side of a semipermeable membrane, and a dialysis fluid is passed on the other side. By altering the composition of the dialysis fluid, the concentrations of undesired solutes (potassium and urea, etc) in the fluid are low and desired solutes (such as sodium) are at their natural concentration as in healthy blood. The undesired solutes, i.e. waste, then diffuse across the membrane into the dialysis fluid and are removed, and the desired solutes will be kept in the natural concentration (Fiore and Ronco 2007).

3. Types of dialysis

According to the techniques, there are three main types of dialysis: hemodialysis, peritoneal dialysis and hemofiltration.

(1) Hemodialysis

In hemodialysis, the patient's blood is passed through a tubing system to a semipermeable membrane which has dialysis fluid running on the other side. Through dialysis, the cleansed blood is then returned through the circuit system back to the body. Ultrafiltration occurs by increasing the hydrostatic pressure of the blood in the dialysis circuit to cause water to cross the membrane down a pressure gradient. The dialysis process is very efficient, allowing the treatment to be undertaken intermittently, usually two or three times a week, about four hours each time. The dialysis is normally done in the hospital, even it can also be done in a patient's home as the home hemodialysis. When dialysis taken, the tubes are kept in patient, and the patients in the dialysis treatment will be a handicapped status. Also, dialysis is high cost.

In contrast to peritoneal dialysis, in which transport is between fairly static fluid compartments, hemodialysis relies on convective tranport and utilizes counter current flow, where the diasylate is flowing in the opposite direction to blood flow in the extracorporeal circuit. Counter-current exchanges maintain the concentration gradient across the membrane at a maximum and increase the efficiency of the dialysis. The efficiency of waste clearance during hemodialysis is much higher than in natural kidneys. Therefore, dialysis treatments do not have to be continuous and can be performed intermittently, typically two or three times per week, or less. Fluid removal (ultrafiltration) is achieved by altering the hydrostatic pressure of the dialysate compartment, causing free water to move across the membrane along a pressure gradient. The dialysis solution is a sterilized solution of mineral ions. Urea and other waste products, such as potassium and phosphate, diffuse into the dialysis solution. However, concentrations of most mineral ions (e.g. sodium) are similar to those of normal plasma to prevent loss (Yucha 2004).

A. Dialysis prescription

A prescription for dialysis by a physician will specify various parameters for setting up dialysis machines, such as time and duration of dialysis sessions. In the United States, 3-4 hours each time and 2-3 times per week are typical. There are also a small number of patients who undergo nocturnal dialysis for 8 hours per night 6 nights per week.

B. Side-effects and complications

Hemodialysis usually also involves the removal of extra fluid, because most patients with end-stage renal failure pass no urine. The sudden removal of fluid on dialysis may cause side effects, which are usually proportionate to the amount of fluid which is removed. These potential side effects include low blood pressure, fatigue, breeding, chest pains, leg-cramps and headaches. Hemodialysis may cause inflammation. Since hemodialysis requires access to the circulatory system, patients undergoing hemodialysis have a portal of entry for microbes, which could lead to septicemia or an infection affecting the heart valves (endocarditis) or bone (osteomyelitis). The risk of infection depends on the type of access used. Blood clotting in the tubing and dialyser is a frequent cause of complications until the routine use of anticoagulants. While anti-coagulants have improved outcomes, they can lead to uncontrolled bleeding. Occasionally, people have severe allergic reactions to anticoagulants. In this case dialysis is done without anticoagulation or the patient is switched to an alternate anticoagulant. Heparin is the most commonly used anticoagulant in hemodialysis patients, as it is generally well tolerated and can be quickly reversed with protamine. A common alternative to heparin is citrate, that is suitable fo the patients who are allergic to heparin (Blossom et al. 2008).

C. Hemodialysis access

There are three primary modes of access to the blood in hemodialysis: an intravenous (IV) catheter, an arteriovenous (AV) Cimino fistula and synthetic graft. The type of access is influenced by factors such as the expected time course of a patient's renal failure and the condition of his/her vasculature. Patients may have multiple accesses, usually because an AV Cimino fistula or synthetic graft is maturing, and a catheter is still used.

D. Catheter

Catheter access, sometimes called a central venous catheter (CVC), consists of a plastic catheter with two lumens (or occasionally two separate catheters) which is inserted into a large vein (usually the vena cava, via the internal jugular vein or the femoral vein) to allow large flows of blood to be withdrawn from one lumen, to go into the dialysis circuit, and to be returned via the other lumen. However, the blood flow is almost always less than that of a well functioning fistula or graft. They are usually found in two general varieties, tunnelled and non-tunnelled.

Tunnelled catheter access involves a longer catheter, which is tunnelled under the skin from the point of insertion in the vein to an exit site some distance away. They are usually placed in the internal jugular vein in the neck and the exit site is usually on the chest wall. The tunnel acts as a barrier to invading microbes and as such tunnelled catheters are designed for short to medium term access, as infection is still a frequent problem.

Non-tunnelled catheter access is for short term access, up to about 10 days, but often for one dialysis session only, and the catheter emerges from the skin at the site of entry into the vein.

Aside from infection, venous stenosis is another serious problem with catheter access. The catheter is a foreign body in the vein, and often provokes an inflammatory reaction in the vein wall, which results in scarring and narrowing of the vein, often to the point where it occludes. This can cause problems with severe venous congestion in the area drained by the vein and may also render the vein, and the veins drained by it, useless for the formation of a fistula or graft at a later date. Patients on longterm hemodialysis can literally 'run-out' of access, so this can be a fatal problem.

Catheter access is usually used for rapid access for immediate dialysis, for tunnelled access in patients who are deemed likely to recover from acute renal failure, and patients with end-stage renal failure, who are either waiting for alternative access to mature, or those who are unable to have alternative access. Catheter access is often popular with patients, as attachment to the dialysis machine doesn't require needles. However the serious risks of catheter access noted above mean that such access should only be contemplated as a long term solution in the most desperate access.

The hemodialysis machine performs the function of pumping the patient's blood and the dialysate through the dialyzer. The newest dialysis machines on the market are highly computerized and continuously monitor an array of safety-critical parameters, including blood and dialysate flow rates, blood pressure, heart rate, conductivity, pH, etc. If any reading is out of normal range, an audible alarm will sound to alert the nurse to se the patient condition.

E. Water system

An extensive water purification system is a basic equipment for hemodialysis. Since dialysis patients are exposed to vast quantities of water, which is mixed with the acid bath to form the dialysate, even trace mineral contaminants or bacterial endotoxins can filter into the patient's blood. Because the damaged kidneys are not able to perform their intended function of removing impurities, ions that are introduced into the blood stream via water can build up to hazardous levels, causing numerous symptoms including death. For this reason, water used in hemodialysis is typically purified using reverse osmosis. It is also checked for the absence of chlorine ions and chloramines, and its conductivity is continuously monitored, to detect the level of ions in the water.

F. Dialyzer

The dialyzer, or artificial kidney, is the piece of equipment that actually filters the blood. One of the most popular types is the hollow fiber dialyzer, in which the blood is run through a bundle of very thin capillary-like tubes, and the dialysate is pumped in a chamber bathing the fibers. The process mimics the physiology of the glomerulus and the rest of the nephron. Pressure gradients are used to remove fluid from the blood. The membrane itself is often synthetic, made of a blend of polymers such as polyarylethersulfone and polyamide. Dialyzers come in many different sizes. A larger dialyzer will usually translate to an increased membrane area, and thus an increase in the amount of solutes removed from the patient's blood. Different types of dialyzers have different clearances for different solutes. I suggest that the dialyzer should be discarded after each treatment and not shared among patients.

G. Pre-dialysis

A dialysis machine should be available first. There are many models of dialysis machines, but typically in modern machines there will be a computer, CRT, a pump, and facility for disposable tubing and filters. The filters (the actual artificial kidneys) are cylindrical, clear plastic outside with the filter material visible inside. They are perhaps 15-18 inches long, and 2-3 inches thick. They have tubing connectors at both ends. The nurse will set up plumbing on the machine in a moderately complex pattern that has been worked out to move blood through the filter, allow for saline drip, allow for various other medications/chemicals to be administered. How the plumbing is set up may vary between models of machine and they types of filters.

The pump does not directly contact the blood or fluid in the plumbing — it works by applying pressure to the tubing, then moving that pressure point around. Think of a disk with a protrusion in it. Put this into a close fitting 270 degree enclosure. Put plastic tubing between the enclosure and the disk, entering and exiting in the 90 open degrees. Now imagine the disk turning. It will put pressure on the tubing, and the pressure point will roll around through the 270 degrees, forcing the fluid to move. It is characteristic of dialysis machines that most of the blood out of the patients body at any given time is visible.

The patient arrives and is carefully weighed. Standing and sitting blood pressures are taken. Temperature is taken.

Access is set up. For patients with a fistula this means inserting two large gauge needles into the fistula. This is painful and a local anaesthetic injection could be done.

When access has been set up, the patient is then connected to the preconfigured plumbing, creating a complete loop through the pump and filter.

F. Dialysis

The pump and a timer are started. Hemodialysis is underway. Periodically (every half hour, nominally) blood pressure is taken. As a practical matter, fluid is also removed during dialysis. Most dialysis patients are on moderate to severe fluid restrictive diets, since kidney failure usually includes an inability to properly regulate fluid levels in the body. A session of hemodialysis may typically remove 2-5 kg of fluid from the patient. The amount of fluid to be removed is set by nurse according to the patient's estimated dry weight. This is a weight that the care staff believes represents what the patient should weight without fluid built up because of kidney failure. Removing this much fluid can cause or exacerbate low blood pressure. Monitoring is intended to detect this before it becomes too severe. Low blood pressure can cause cramping, nausea, shakes, dizziness, lightheadedness, and unconsciousness. During dialysis, occasionally, patients have low blood pressure and lose consciousness. Often this is temporary and passes after the head is placed down for a short time.

G. Post-dialysis

At the end of the prescribed time, the patient is disconnected from the plumbing - blood lines. Needle wounds are bandaged with gauze, held for up to 1 hour with direct pressure to stop bleeding, and then taped in place. The process is similar to getting blood drawn, only it is lengthier, and more fluid or blood is lost.

Temperature, standing and sitting blood pressure, and weight are all measured again. Temperature changes may indicate infection. BP discussed above. Weighing is to confirm the removal of the desired amount of fluid.

Care staff verifies that the patient is in condition suitable for leaving. The patient must be able to stand, maintain a reasonable blood pressure, and be coherent. Different rules apply for in-patient treatment.

H. Post-dialysis washout.

Following haemodialysis, patients may experience a syndrome called "washout". The patient feels weak, tremulous, extreme fatigue. Patients report they "are too tired, too weak to converse, hold a book or even a newspaper." It may also vary in intensity ranging from whole body aching, stiffness in joints and other flu-like symptoms including headaches, nausea and loss of appetite. The syndrome may begin toward the end of treatment or minutes following the treatment. It may last 30 minutes or 12-14 hours in a dissipating form. Patients though exhausted have difficulty falling to sleep. Eating a light meal, rest and quiet help the patient cope with washout until it has 'worn away.

(2) Peritoneal dialysis

In peritoneal dialysis, a special solution is run through a tube into the peritoneal cavity, the abdominal body cavity around the intestine, where the peritoneal membrane acts as a semipermeable membrane. The fluid is left there for a period of time to absorb waste products, and then is removed through the tube. This is usually repeated a number of times during the day. Ultrafiltration occurs via osmosis in this case, as the dialysis solution is supplied in varying osmotic strengths to allow for some control over the amount of fluid to be removed. The dialysis process in this case is less efficient than hemodialysis and is carried out daily, but the ultrafiltration process is slower and gentler.

Peritoneal dialysis works on the principle that the peritoneal membrane that surrounds the intestine, can act as a natural semipermeable membrane, and that if a specially formulated dialysis fluid is instilled around the membrane then dialysis can occur, by diffusion. Excess fluid can also be removed by osmosis, by altering the concentration of glucose in the fluid.

Dialysis fluid is instilled via a peritoneal dialysis catheter, which is placed in the patient's abdomen, running from the peritoneum out to the surface, near the navel. This is done as a short surgery. Peritoneal dialysis is typically done in the patient's home and workplace, but can be done almost anywhere; a clean area to work, a way to elevate the bag of dialysis fluid and a method of warming the fluid are all that is needed. The main consideration is the potential for infection with a catheter; peritonitis is a commonest serious complication, and infections of the catheter exit site or tunnel are less serious but more frequent. Because of this, patients are advised to take a number of precautions against infection (Rippe et al. 2007).

(3) Hemofiltration

Hemofiltration is a similar treatment to hemodialysis, but in this case, the membrane is far more porous and allows the passage of a much larger quantity of water and solutes to pass across it. The fluid which passes across the membrane is discarded and the remaining blood in the circuit has its desired solutes and fluid volume replaced by the addition of a special hemofiltration fluid. It is a slow continuous therapy with sessions typically lasting 12-24 hours, usually daily. This, and the fact that ultrafiltration is very slow and thus gentle, makes it ideal for patients in intensive care units, where acute renal failure is common. A combination of hemofiltration and hemodialysis, called hemodiafiltration (incorporating a hemofilter to a standard hemodialysis circuit), is being used in some centres for chronic maintenance therapy (Mahdavi-Mazdeh et al. 2008).

Peritoneal dialysis (PD) has been used as a home dialysis therapy for renal replacement for more than 30 years. A high proportion of PD patients are overhydrated. Clinical assessment of dry weight in PD patients is difficult and further complicated by the paucity of signs and symptoms indicative of dehydration. Bioimpedance analysis technique has been considered as a potential tool to measure body fluid non-invasively, inexpensively and simply (Zhu et al. 2006).

Correspondence to:
Hongbao Ma, PhD
Bioengineering Department
Zhengzhou University
100 Science Road
Zhengzhou, Henan 450001, China
Email: hongbao@gmail.com
Telephone: 01186-137-8342-5354

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